Literature Review and Analysis of Coastal Urbanization and Microbial Contamination of Shellfish Growing Areas

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Keywords: shellfish, urbanization, pathogen, water quality, impervious cover, microbial pollution

Abstract

Clean water is the key factor for determining the suitability of coastal areas for growing and harvesting shellfish. Clams, oysters and other filter-feeding shellfish can accumulate contaminants that may be present in the coastal environment. Shellfish growing areas are particularly vulnerable to fecal pollution from sewage systems, farm animal wastes, stormwater runoff, wildlife and other sources because of the health risks associated with enteric viruses and other pathogens. Pollution impacts are exacerbated by changes in land use, land cover and watershed hydrology associated with urbanization. Microbial pollution is chronic and pervasive in many coastal areas and is closely correlated with population densities, development levels, rainfall events, stormwater runoff and river flows. Moderate levels of development in the range of 10 to 25 percent impervious cover correlate with degraded aquatic habitats, including shellfish growing areas. Shellfish waters are vulnerable to contamination at even lower levels of development if there are raw sewage discharges or if natural hydrologic processes are disrupted and there is high connectivity between upland pollution sources and shellfish waters. These findings underscore the importance of preserving natural land cover and hydrologic systems for buffering pollution impacts and preserving coastal waters for shellfish harvesting.

Introduction

Many factors influence the suitability of coastal areas for growing and harvesting shellfish, and none is more vital than clean water. Human habitation has had a dramatic effect on the condition of the nation's coastal habitats and resources. A primary concern in shellfish growing areas is microbial contamination from human and animal feces and related health risks associated with the consumption of contaminated bivalve molluscan shellfish (e.g., oysters, clams, mussels). Key sources of fecal pollution include discharges from municipal sewage treatment plants, on-site sewage systems, stormwater runoff, marinas and boaters, farm animals, pets and wildlife.

The condition and classification of shellfish growing areas tend to correlate with population densities and development levels in adjacent watersheds (Figure 1), but our limited understanding of these relationships hampers efforts to permanently safeguard water quality for shellfish harvesting (Figure 2). To better understand and address these issues, the Puget Sound Action Team initiated a study to assess the effects of urbanization on shellfish growing areas that included a literature review and analysis, completed in June 2004.

photo courtesy Taylor Shellfish Farms, Inc.

Figure 1: The watersheds and waters of Elliot Bay, King County (closed to commercial harvesting) and Totten Inlet, Thurston County (open to commercial harvesting) differ significantly in their suitability for growing and harvesting bivalve molluscan shellfish. Are there measurable correlations between watershed development and nearshore bacterial levels? If so, what are the mechanisms that drive these relationships? Which landscape indicators correlate most strongly with nearshore bacterial levels?

Effects of Urbanization on Watershed Hydrology and Water Quality

Numerous studies have documented the effects of development on the condition of streams, nearshore habitats and other aquatic ecosystems. Impacts include the fragmentation and loss of habitat and the degradation of water resources and water quality.

"Of all the land use changes affecting the hydrology of an area, urbanization is by far the most forceful" (Leopold 1968). A central issue is the change in flow regime, particularly the loss of water storage in the soil column in the Pacific Northwest's native rain forests (Booth 2000). Effects begin with the first expression of human activity in a watershed and then progress as development increases in scope and scale (Booth *et al*. 2001). Clearing of land cover and construction of impervious surfaces converts large volumes of water from subsurface flows to surface runoff. The landscape's capacity to attenuate flows and break down pollutants is further reduced as other features of the terrain are ditched, drained, piped and armored to efficiently shed runoff. This combination of reduced retention and enhanced conveyance causes increased flooding, degraded stream channels, reduced ground-water recharge, lower stream baseflows, and polluted surface waters and shellfish beds.

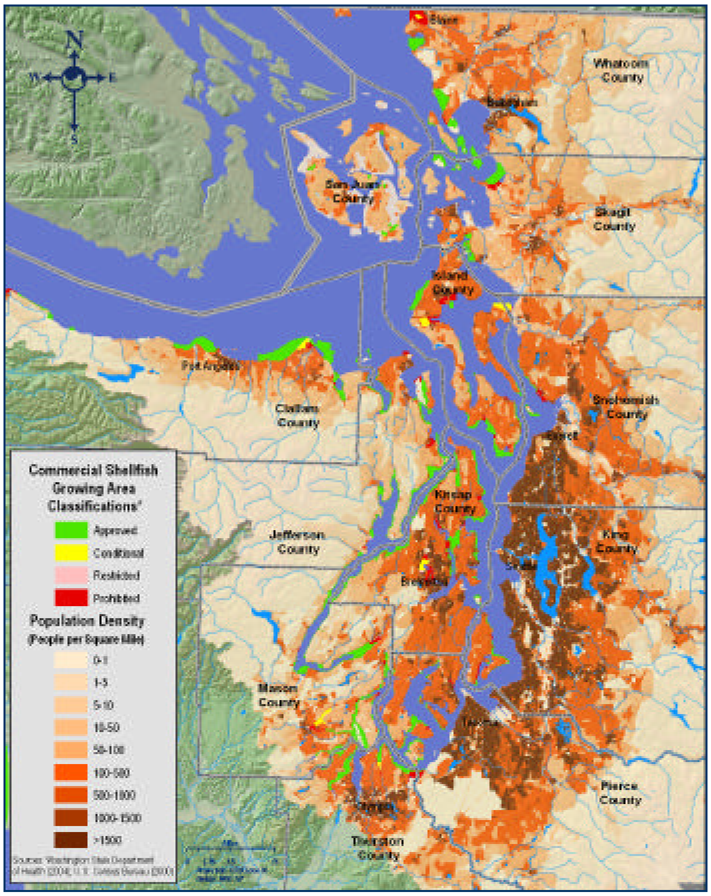

Figure 2. Population densities and commercial shellfish growing area classifications in Puget Sound. Shellfish areas not officially classified are closed to commercial harvest, including the shoreline area along the Everett-to-Tacoma urban corridor.

Selected Studies of Urbanization and Shellfish Contamination

Mailo and Tschetter 1981. Correlated population increases in two North Carolina counties with degraded water quality and shellfish closures. Attributed impacts mainly to growth that had outstripped the region's sewage management capacity.

Duda and Cromartie 1982. Documented sharp increases in development and shellfish closures in coastal North Carolina. Correlated bacterial levels with densities of on-site sewage systems and identified stormwater runoff and drainage modifications as contributing factors.

Macfarlane 1996. Attributed shellfish closures in Cape Cod, Massachusetts, with rapid development and loadings from storm-water, on-site sewage systems and wildlife. Restoration efforts focused on installation of stormwater treatment systems.

Weiskel *et al*. 1996. Assessed bacterial sources, pathways and loadings in Massachusetts' Buttermilk Bay watershed. Determined that stormwater runoff contributed nearly a quarter of the bacterial load, had a disproportionately high impact on nearshore water quality, and correlated strongly with urban land uses.

White *et al*. 2000. Correlated bacterial loads and shellfish closures in the lightly developed Jumping Run Creek watershed of North Carolina with ditching, bulkheading and other hydrologic modifications that enhanced runoff and drainage.

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Mallin *et al*. 2000, 2001. Correlated bacterial levels and shellfish closures in North Carolina tidal creeks with population growth on a regional scale, and with population, developed land, and impervious cover on a watershed scale (Figure 3). Further analysis highlighted the importance of limited impervious cover and intact land cover and wetland systems in mitigating coastal microbial contamination.

Lipp *et al*. 2001a, 2001b. Correlated concentrations and spatial and seasonal distribution of bacterial loadings with freshwater flows and densities of on-site sewage systems in Florida's Charlotte Harbor and Sarasota Bay. Identified subsurface flows, surface runoff and tides as key physical factors.

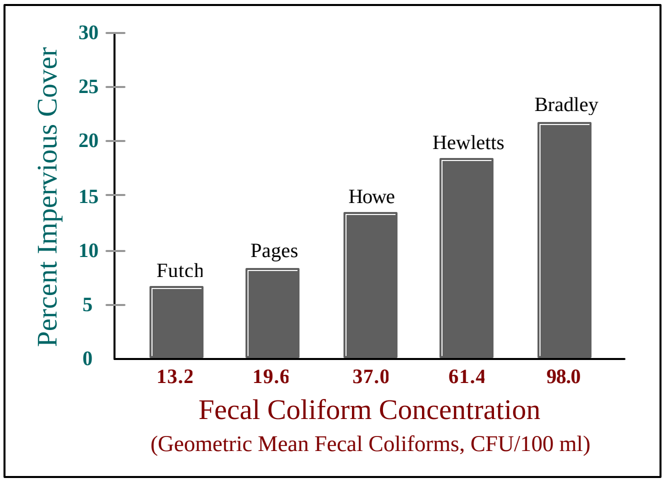
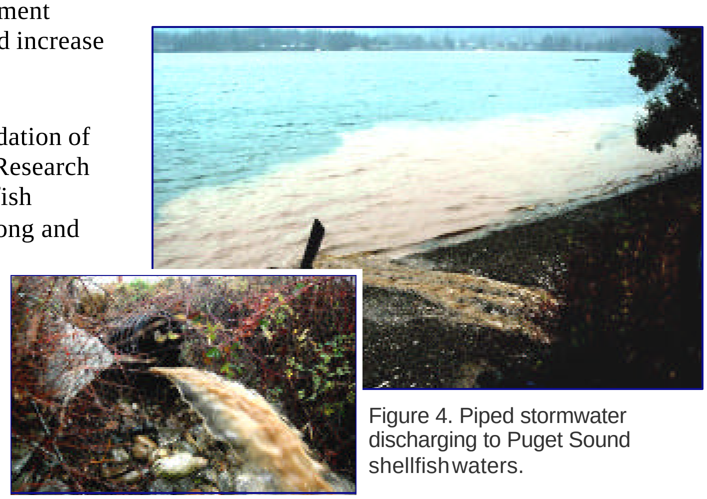


Figure 3. Sample results correlating impervious cover and bacterial levels in North Carolina tidal creeks (Mallin *et al.* 2001).

Kelsey *et al*. 2003, 2004. Employed a variety of techniques to compare land uses and ecosystem responses in urban Murrells Inlet and rural North Inlet of South Carolina. Attributed greater bacterial contamination and differences in bacterial profiles in Murrells Inlet to urban influences, primarily stormwater runoff.

Conclusions

- Two significant and related trends—population growth and urbanization—are stressing and degrading coastal ecosystems.
- Bivalve molluscan shellfish are efficient vectors of enteric viruses and other pathogens. Actions that prevent contamination of shellfish growing areas are vital for safeguarding public health.
- Microbial contamination is chronic in many coastal areas of the country and correlates with population densities, development levels, rainfall events, stormwater runoff and river flows. Urbanization dramatically reduces the capacity of watersheds to attenuate flows and contaminants. The imprint of urbanization is generally permanent and the related impacts are equally difficult to mitigate or reverse.
- Pollution impacts are exacerbated by development practices that disrupt hydrologic processes and increase connectivity between pollution sources and downstream waters (Figure 4).
- Research correlating development with degradation of stream systems is extensive and compelling. Research on nearshore marine systems, including shellfish growing areas, is more limited but reveals strong and similar relationships.
- Impervious cover is the most widely researched landscape indicator for measuring the effects of development. Both freshwater and marine systems exhibit a continuum of effects that surface at low levels of development (<10 percent impervious cover) then amplify as development progresses.



photos courtesy Liberty Bay Foundation

Figure 4. Piped stormwater discharging to Puget Sound shellfish waters.

- The scientific literature supports long-standing observations that urban development is incompatible with safe shellfish harvesting, but does not reveal a universal rule or threshold for determining suitable land uses and development levels.
- Pollution impacts can be mitigated, but not eliminated, using a variety of approaches. Sound land use planning, pollution prevention, watershed protection and personal stewardship are needed to guide appropriate development practices.

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Acknowledgments

Our appreciation to USEPA for financial assistance and to members of the project advisory committee, including Harriet Beale, Robin Downey, Bob Woolrich, Tim Determan, Marina Alberti, Marcie Bidwell, Mindy Roberts, Liz Lyman, Scott Clark, Kevin Dragon, Paul Williams, Chris May, Stuart Whitford, Shawn Ultican, Sylvia Goodwin, Jeff Chalfant and Chris Parsons.